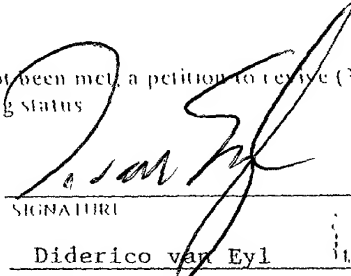


page 1 of 2

U.S. APPLICATION NO. (if known see 37 CFR 1.5)		INTERNATIONAL APPLICATION NO.		ATTORNEY'S DOCKET NUMBER	
To: <b>09/529680</b>		PCT/EP98/06375		Mo-5599/LeA 32,647	
17. <input checked="" type="checkbox"/> The following fees are submitted.				CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5))					
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO				\$840.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO				670.00	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO				760.00	
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)				970.00	
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)				96.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$ 840.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e))				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	2 - 20 =		x \$ 18.00	\$	
Independent claims	2 - 3 =		x 78.00	\$	
ADDITIONAL DEPENDENT CLAIM(S) (if applicable)			1 260.00	\$	
TOTAL OF ABOVE CALCULATIONS =				\$	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28)				\$	
SUBTOTAL =				\$	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f))				\$	
TOTAL NATIONAL FEE =				\$ 840.00	
Fee for recording the enclosed assignment (37 CFR 1.21(b)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) \$40.00 per property.				\$ 40.00	
TOTAL FEES ENCLOSED =				\$ 880.00	
				Amount to be refunded \$	
				charged \$	
<p>a <input type="checkbox"/> A check in the amount of \$ _____ to cover the above fees is enclosed</p> <p>b <input checked="" type="checkbox"/> Please charge my Deposit Account No. <u>13-3848</u> in the amount of \$ <u>880.00</u> to cover the above fees. A duplicate copy of this sheet is enclosed.</p> <p>c <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>13-3848</u>. A duplicate copy of this sheet is enclosed.</p>					
<p>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.</p> <p>SEND ALL CORRESPONDENCE TO:</p> <p>Bayer Corporation Patent Department 100 Bayer Road Pittsburgh, PA 15205-9741</p>					
				<p></p> <p>SIGNATURE</p> <p>Diderico van Eyl</p> <p>NAME</p>	
				<p>38,641</p> <p>REGISTRATION NUMBER</p>	

09/529680

416 Rec'd PCT/PTO 17 APR 2000

PATENT APPLICATION  
Mo-5599  
LeA 32,647

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION OF )  
GERHARD WÖTTING ET AL ) PCT/EP98/06375  
SERIAL NUMBER: TO BE ASSIGNED )  
FILED: HEREWITH )  
TITLE: SILICON NITRIDE SUBSTANCES )  
CONTAINING SINTERING ADDI- )  
TIVES AND SiO<sub>2</sub>, METHOD FOR )  
PRODUCING THEM AND USE OF )  
THE SAME )

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Applicants respectfully request entry of the following amendments prior to examination of the above-mentioned patent application.

IN THE CLAIMS:

1. (Amended) Silicon nitride materials containing sintering aids and SiO<sub>2</sub> and a grain boundary phase, [characterized in that] wherein the molar ratio of the silicon dioxide in the grain boundary phase to the sintering additives including SiO<sub>2</sub> in the grain boundary phase is >60% and the oxide nitride content <1%.
2. (Amended) A process [Process] for producing silicon nitride materials [according to Claim 1, characterized in that] wherein, either alone or in combination,


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Donna J. Veatch

(Name of person mailing paper or fee)

  
Signature of person mailing paper or fee)

- a) the  $\text{Si}_3\text{N}_4$  powder used, either alone or together with the sintering aids, is thermally oxidized,
- b) the  $\text{Si}_3\text{N}_4$  powder, either alone or together with the sintering aids and, if desired, further additives, is tribooxidized during milling and/or
- c) the  $\text{Si}_3\text{N}_4$  powder is admixed with sintering aids or with  $\text{SiO}_2$  or at least one  $\text{SiO}_2$ -forming component either before or during milling[.]  
wherein the silicon nitride materials contain sintering aids and  $\text{SiO}_2$ , and a grain boundary phase in which the molar ratio of the silicon dioxide in the grain boundary phase to the sintering additives including  $\text{SiO}_2$  in the grain boundary phase is >60% and the oxide nitride content <1%.

Please delete Claim 3.

IN THE SPECIFICATION:

In the title, delete the title and insert --SILICON NITRIDE SUBSTANCES CONTAINING SINTERING ADDITIVES AND  $\text{SiO}_2$ , METHOD FOR PRODUCING THEM AND USE OF THE SAME--.

At page 1, below the title, please add:

--BACKGROUND OF THE INVENTION--.

At page 2, above line 15, please add:

--DESCRIPTION OF THE INVENTION--.

At page 5, line 31, after "character," please add:

--All parts and percentages are by weight unless otherwise indicated.--

At page 8, below line 22, please add:

--Although the present invention has been described in detail with reference to certain preferred versions thereof, other variations are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the versions contained therein.--

Please add the following Abstract, submitted herein separately:

--SILICON NITRIDE SUBSTANCES CONTAINING SINTERING ADDITIVES  
AND SiO<sub>2</sub>, METHOD FOR PRODUCING THEM AND USE OF THE SAME

ABSTRACT OF THE DISCLOSURE

The invention relates to silicon nitride substances containing sintering additives and SiO<sub>2</sub>, a method for producing them and the use of the same.--

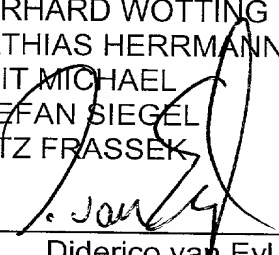
REMARKS

Entry of this Preliminary Amendment is requested. The amendments made above have been made to place the application in conformance with American patent practice. No new matter has been added. Claim 3 was deleted.

Respectfully submitted,

GERHARD WÖTTING  
MATHIAS HERRMANN  
GRIT MICHAEL  
STEFAN SIEGEL  
LUTZ FRASSEK

By

  
\_\_\_\_\_  
Diderico van Eyl  
Attorney for Applicants  
Reg. No. 38,641

Bayer Corporation  
100 Bayer Road  
Pittsburgh, Pennsylvania 15205-9741  
(412) 777-4802  
FACSIMILE PHONE NUMBER:  
(412) 777-5449  
s:\ks\DV0251

Silicon nitride materials containing sintering aids and SiO<sub>2</sub>, a process for producing them and their use

5 The present invention relates to silicon nitride materials containing sintering aids and SiO<sub>2</sub>, a process for producing them and their use.

10 Ceramic materials are finding ever wider use in the construction of machinery and apparatus, in particular in bearings (Ceramic Airframe Bearings: Lubrications Engineering, 31 (1975), 558-564). All-ceramic bearings have proven useful particularly in applications where there is little lubrication and in corrosive media. However, it has been found in a wide variety of application areas for components made of high-performance ceramic that they degrade and that their life cannot be reliably predicted. The corrosion resistance is dependent to a considerable extent on the type of corrosive medium, the material composition and the superposed mechanical stress. The cause of this is the different reaction behaviour of the individual components of the microstructure of the ceramics (matrix grains, grain boundary phases, impurities) towards acids, bases or under hydrothermal conditions. Liquid-phase-sintered materials such as silicon nitride or silicon carbide (LPSSIC) which contain from 5 to 20% by volume of grain boundary phases display attack along the grain boundary phase in acids and bases. In general, the main point of attack in acid and alkali corrosion in the temperature range <180°C is the grain boundary phase. However, this is not leached out entirely, which is made clear by materials which are corroded through to the centre still having strengths of from 300 to 400 MPa.

The corrosion rates for corrosion in the acid range are strongly dependent on the material composition. EP-A 649 824 discloses that MgO/Al<sub>2</sub>O<sub>3</sub>-containing materials have good acid resistance without the cause of this behaviour being completely known. One way of further improving the acid resistance of silicon nitride materials containing rare earth metal oxides, Y<sub>2</sub>O<sub>3</sub> and possibly Al<sub>2</sub>O<sub>3</sub> as sintering aids is to reduce the amount of these sintering aids. However, the resulting improvement in the

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Donna J. Yeatch

(Name of person mailing paper or fee)

  
Signature of person mailing paper or fee

corrosion resistance has to be bought by higher manufacturing costs, since HIP technology is required for densification (EP-A 414 383). Furthermore, Mater. Res. Soc. Symp. Proc. 287 (1993) and Key Engineering Materials 113 (1996), pp. 227-237, report that corrosion is reduced at very high concentrations of acids, which in the case of phosphoric acid could be explained by formation of a passive layer, see Corrosion of High Performance Ceramics; Springer Verlag, Berlin, 1992; pp. 76 to 78.

There is therefore a great need for acid-stable ceramic materials.

It is therefore an object of the invention to provide ceramic materials based on  $\text{Si}_3\text{N}_4$  which have a high corrosion resistance, i.e., for example, a low mass change and low strength losses after acid treatment.

It has now been found that a silicon nitride material has, regardless of the way in which it is produced, a high corrosion resistance towards acids if it has a very high  $\text{SiO}_2$  content and formation of silicon oxide nitride is avoided, i.e. if the molar ratio of the silicon dioxide in the grain boundary phase to the sintering aids including  $\text{SiO}_2$  in the grain boundary phase is  $>60\%$  and the oxide nitride content ( $\text{Si}_2\text{N}_2\text{O}$  content) is  $<1\%$ .

The invention accordingly provides silicon nitride materials containing sintering aids and  $\text{SiO}_2$  and having a molar ratio of the silicon dioxide in the grain boundary phase to the sintering aids including  $\text{SiO}_2$  in the grain boundary phase is  $>60\%$ , preferably  $>65\%$ , and the oxide nitride content ( $\text{SiO}_2\text{N}_2\text{O}$ ) is  $<1\%$ .

For the purposes of the present invention, sintering aids are the added substances which form the liquid phase during sintering and remain in the grain boundary phase.

The grain boundary phase in silicon nitride materials is formed by solidification of the liquid phase present during sintering. It contains the sintering additives, silicon

dioxide and sometimes dissolved silicon nitride. Depending on the conditions of the thermal treatment (cooling rate, etc), it is amorphous or partially crystalline. In general, it wets the silicon nitride particles and forms a three-dimensional network.

5 Sintering aids present in the grain boundary phase for the purposes of the invention are preferably  $Y_2O_3$ ,  $Sc_2O_3$ , rare earth metal oxides, alkaline earth metal oxides and  $Al_2O_3$ .

10 The amount of the added sintering aids +  $SiO_2$  is preferably selected so that the proportion of grain boundary phase in the sintered material is  $< 20\%$  by volume, particularly preferably  $0.1 - 17\%$  by volume, very particularly preferably from 3 to  $15\%$  by volume.

15 In one embodiment of the invention, the silicon nitride materials contain further additives.

20 Such additives are, for example, reactive additives, i.e. ones which react with  $Si_3N_4$  and form  $SiO_2$ , for example  $TiO_2$ ,  $WO_3$  and/or  $MoO_3$ . Thus,  $TiO_2$ , for example, reacts to form  $TiN$ , while, for example,  $WO_3$  and  $MoO_3$  form silicides with simultaneous oxidation of  $Si_3N_4$  to  $SiO_2$ .

25 It is likewise possible to use additives which are retained as disperse phases, for example  $SiC$ ,  $TiN$ ,  $MoSi_2$ ,  $TiCN$  and/or  $HfO_2$  or else additives which form mixed crystals with the  $Si_3N_4$ , for example  $AlN$ .

The additives which react with  $Si_3N_4$  and form  $SiO_2$  are preferably present in an amount of from 0 to  $10\text{ mol}\%$ , preferably  $< 5\text{ mol}\%$ , based on  $Si_3N_4$ .

30 The additives remaining as a disperse phase are preferably present in an amount of from 0 to  $30\%$  by volume.



Additives which form mixed crystals are preferably present in amounts of from 0 to 50 mol%, preferably <15 mol%, based on  $\text{Si}_3\text{N}_4$ .

In a preferred embodiment of the invention, the porosity of the material is <2%.

5

The invention additionally provides a process for producing the material of the invention, in which, either alone or in combination,

- 10 a) the  $\text{Si}_3\text{N}_4$  powder used, either alone or together with the sintering aids and, if desired, further additives, is thermally oxidized or
- b) the  $\text{Si}_3\text{N}_4$  powder, either alone or together with the sintering aids and, if desired, further additives, is tribooxidized during milling or
- 15 c) the  $\text{Si}_3\text{N}_4$  powder is admixed with sintering aids or with  $\text{SiO}_2$  or at least one  $\text{SiO}_2$ -forming component either before or during milling.

Any commercial  $\text{Si}_3\text{N}_4$  powder can be used for the processes according to a), b) and c).

20

The thermal oxidation a) is carried out in an oxidizing atmosphere, preferably in air,  $\text{O}_2$  and/or water vapour at temperatures of from 300 to 1400°C. In the variant a), a milling step can also be carried out before or after the oxidation.

25 The tribooxidation b) during milling is carried out by intensive milling of the  $\text{Si}_3\text{N}_4$  powder dry or in a liquid such as  $\text{H}_2\text{O}$  or an organic solvent, e.g. acetone, hexane or alcohol.

Milling is preferably carried out in ball mills and is continued until the milled  $\text{Si}_3\text{N}_4$  has a mean particle size ( $d_{50}$ ), preferably measured by means of a Master Sizer S, of

30

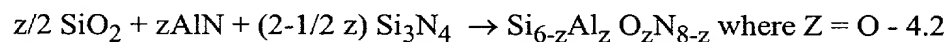
< 2.5  $\mu\text{m}$ , preferably < 1  $\mu\text{m}$ , and has the required molar ratio of  $\text{SiO}_2$  to sintering aids.

5 In the variant c), the  $\text{SiO}_2$ -forming components used can be siloxanes, silanes, silicone resins (see Material Science and Technology Vol. 178, Processing of Ceramics, VCH, Weinheim, (1996) Part II, 4-47, DE-A 43 18 974, EP-A 0 412 428, or the reactive additives described, e.g.  $\text{TiO}_2$ ,  $\text{WO}_3$  and  $\text{MoO}_3$ .

10 The amount of  $\text{SiO}_2$ -forming components is dependent on the desired  $\text{SiO}_2$  content of the sintered body.

15 The production of the sintered material from the powder mixtures obtained according to the variants a), b) and/or c) is preferably carried out using generally customary ceramic technology.

20 The incorporation of the sintering aids or the additives which form mixed crystals and/or  $\text{SiO}_2$  into the silicon nitride crystal lattice can also influence the ratio of  $\text{SiO}_2$  to the sintering aids. In this case, when determining the  $\text{SiO}_2$ /sintering aid ratio, the proportion of the original sintering aids or  $\text{SiO}_2$  has to be reduced by the proportion incorporated into the crystal lattice. This is of particular significance in the case of  $\alpha'$ - and  $\beta'$ - $\text{SiAlONs}$ , e.g. according to the following equation:



25 This has to be taken into account when calculating the amounts to be weighed out.

The invention additionally provides for the use of the materials of the invention in the construction of machinery and apparatus, in particular in bearings.

30 The following examples serve to illustrate the invention without having any limiting character.

## Examples

### Example 1

5         $\text{Si}_3\text{N}_4$  powder (Baysinid<sup>®</sup>, obtainable from Bayer AG),  $\text{Y}_2\text{O}_3$  (grade fine, obtainable from H.C. Starck) and  $\text{Al}_2\text{O}_3$  powder (AKP-50<sup>®</sup>, obtainable from Sumitomo) and  $\text{TiO}_2$  (P25, obtainable from Degussa) are mixed in amounts corresponding to the composition indicated in Table 1, homogenized in a stirred ball mill in aqueous suspension for 3 hours, spray dried and pressed to form bodies having dimensions of  
10        50 x 60 x 8 mm. The particle size ( $d_{50}$ ) of the mix after homogenization was 0.5  $\mu\text{m}$ , measured by means of a Master Sizer S at pH 11.0. The bodies are baked out at 600°C for 1 hour in air. They are sintered under gas pressure at 1830°C and 50 bar of  $\text{N}_2$  for 1.5 hours. The weight losses of the specimens were from <0.3 to 1.8%, depending on the  $\text{TiO}_2$  content of the mix. The sintered specimens are cut into test  
15        bars and the surfaces were ground.

Mix 1 b was milled for 6 hours at a higher rotational speed in order to increase the oxygen content.

### 20        Example 2

This example was carried out using a method analogous to Example 1. The deviations are described below.

25        Examples 2a and 2b were prepared using a method analogous to Example 1b.

The sintering of Example 2a was carried out in a BN-coated graphite crucible in a BN powder bed. The weight loss was 1.8%. In Example 2b, the sample was sintered in an RBSN crucible. The weight loss was 0.2%.

In Example 2c, 1.5% of silicone resin was additionally used as binder. Examples 2e and 2f were produced from silicon nitride powder produced by the plasma method and having a surface area of 60 m<sup>2</sup>/g and an SiO<sub>2</sub> content of 8%. The specimens were hot pressed at 1800°C.

5

**Example 3**

The test specimens were produced using a method similar to Example 1. Densification was carried out by a sinter-HIP method, and the weight loss was reduced to < 1.5% by means of the RBSN crucible and a high sample volume/available volume ratio.

10

**Example 4**

The test specimens were produced using a method analogous to Example 2.

15

**Example 5**

The test specimens were produced using a method analogous to Example 1, with sintering being carried out at 1800°C.

20

The respective results are listed in Table 1. By way of example, the mass losses of Examples 1-4 recorded in the corrosion resistance test are shown in Fig. 1.

The following measurement methods were employed for determining the data reported in Table 1:

25

Flexural test bars having dimensions of 3 x 4 x 50 mm were cut from the sintered bodies and used to determine the mechanical properties and the corrosion performance.

30

The strength was determined by means of the 4-point method (support spacing: 20/40 mm).

5 The corrosion performance was determined in thermostated glass vessels using 1 N acid. The acid/solid ratio was >200 ml/10 g of specimen. The acid was changed every 100 hours. The mass loss of the specimens was determined by periodic weighing at defined time intervals (see  $\Delta m$  in Tab. 1). The specimens were rinsed with distilled water and dried before weighing.

10 The oxide nitride content was determined on the specimens by means of XRD measurements. This was carried out using  $\text{CuK}\alpha$  radiation. The quantitative determination was carried out by means of a Rietveld programme (Refine++). The detection limit was 0.8% by mass of  $\text{Si}_2\text{N}_2\text{O}$ .

15 The oxygen content was determined by the hot gas extraction method. The error was <0.1% by mass. The  $\text{SiO}_2$  content was calculated from the oxygen content.

20 The porosity was determined in polished sections (prepared as described in Practical Metallography, 27 (1990, 503-513)) at a magnification of 1000 by means of automatic image analysis (Quantiment 570). The proportion by area of the pores in the polished section was taken as the proportion by volume. In parallel thereto, the density was determined by the Archimedes method, in accordance with EN 993-1.

**Table 1** Compositions and corrosion performance of the materials

No.	Additives	SiO <sub>2</sub> <sup>x</sup> (additive + SiO <sub>2</sub> ) mol%	Si <sub>2</sub> N <sub>2</sub> O/(Si <sub>2</sub> N <sub>2</sub> O) + βSi <sub>3</sub> N <sub>4</sub> Oxide nitride content %	Properties uncorroded		Corrosion conditions	Properties of corroded specimens		
				Porosity	σ <sub>4b</sub> MPa		Δm(100h), mg/cm <sup>2</sup>	Δm(500h), mg/cm <sup>2</sup>	σ <sub>4b</sub> , MPa (500h)
1a	C 5Y <sub>2</sub> O <sub>3</sub> 2Al <sub>2</sub> O <sub>3</sub> 1 TiO <sub>2</sub>	45	0	<0.5	850	in HCl, 60°C	5.6	8.5	450
1b	I 5Y <sub>2</sub> O <sub>3</sub> 2Al <sub>2</sub> O <sub>3</sub> 1 TiO <sub>2</sub> +SiO <sub>2</sub>	65	0	<0.5	850		0.3	0.3	800
1c	I 5Y <sub>2</sub> O <sub>3</sub> 2Al <sub>2</sub> O <sub>3</sub> 5 TiO <sub>2</sub>	74	0	<0.5	825		0.24	0.26	750
1d	C 5Y <sub>2</sub> O <sub>3</sub> 2Al <sub>2</sub> O <sub>3</sub> 7.5 TiO <sub>2</sub>	80.4	33	<0.5	800		7.5	9.5	550
2a	C 5Y <sub>2</sub> O <sub>3</sub> 3Al <sub>2</sub> O <sub>3</sub>	30	0	<0.5	800	in HCl, 60°C	10	16	450
2b	I 5Y <sub>2</sub> O <sub>3</sub> 3Al <sub>2</sub> O <sub>3</sub>	74	0	<0.5	820		0.2	0.2	750
2c	I 5Y <sub>2</sub> O <sub>3</sub> 3Al <sub>2</sub> O <sub>3</sub>	72	0	<0.5	800		0.21	0.23	730
2d	C 5Y <sub>2</sub> O <sub>3</sub> 3Al <sub>2</sub> O <sub>3</sub>	30	0	<0.5	820	in H <sub>2</sub> SO <sub>4</sub> , 60°C	9	-	450
2e	I 5Y <sub>2</sub> O <sub>3</sub> 3Al <sub>2</sub> O <sub>3</sub> + SiO <sub>2</sub>	63	0	<0.5	725		0.32	0.38	650
2f	C 5Y <sub>2</sub> O <sub>3</sub> 3Al <sub>2</sub> O <sub>3</sub> + SiO <sub>2</sub>	81	27	<0.5	765		2.2	8.3	530
3	I 5Y <sub>2</sub> O <sub>3</sub> 1.5 Al <sub>2</sub> O <sub>3</sub> + 0.5 TiO <sub>2</sub>	63	0	<0.5	800	in H <sub>2</sub> SO <sub>4</sub> , 60°C	0.35	0.5	700
4	C 3Y <sub>2</sub> O <sub>3</sub> 1.8 Al <sub>2</sub> O <sub>3</sub>	75.3	12	<0.5	730		1.4	4.5	520
5a	I 3MgO 2 Al <sub>2</sub> O <sub>3</sub>	75	0	<0.5	820	in H <sub>2</sub> SO <sub>4</sub> , 60°C	0.1	0.1	750
5b	C 3MgO 2 Al <sub>2</sub> O <sub>3</sub>	45	0	<0.5	730		0.3	0.45	630

C = comparative example; I = example according to the invention

2a mass loss on sintering = 1.6%; 2b mass loss on sintering = 0.2%

x in the grain boundary phase

## Discussion of the results:

5 The material described in EP-A 649 824 was reproduced in Example 1 without controlling the oxygen content and, under our conditions, displays a mass loss of 8.5 mg/cm<sup>2</sup>. Setting the SiO<sub>2</sub> content leads to an improvement in the corrosion performance of nominally identical materials by a factor of 30 (as demonstrated by Examples 1a and 1b). The importance of controlling the oxygen content not only in preparation of the mix is shown by comparison of Example 2a with Examples 2b and 2c. While sintering of the material in Example 2a leads to a high weight loss which  
10 drastically reduces the SiO<sub>2</sub> content of the sintered material, specimens which were sintered under controlled conditions and have a small weight loss (2b and 2c) display the favourable corrosion performance sought.

15 It is found that the high SiO<sub>2</sub> content leads to a change in the corrosion kinetics. While conventional materials have a linear relationship between corrosion layer thickness and reaction time up to corrosion layer thicknesses of several 100 μm, in the case of the materials of the invention, passivation occurs after only a few μm reaction depth (Fig. 2). This passivation occurs all the more quickly, the lower the additive content and the lower the grain size of the silicon nitride grains in the  
20 material.

**Claims**

1. Silicon nitride materials containing sintering aids and  $\text{SiO}_2$ , characterized in that the molar ratio of the silicon dioxide in the grain boundary phase to the sintering additives including  $\text{SiO}_2$  in the grain boundary phase is  $>60\%$  and the oxide nitride content  $<1\%$ .
2. Process for producing silicon nitride materials according to Claim 1, characterized in that, either alone or in combination,
- a) the  $\text{Si}_3\text{N}_4$  powder used, either alone or together with the sintering aids, is thermally oxidized,
- b) the  $\text{Si}_3\text{N}_4$  powder, either alone or together with the sintering aids and, if desired, further additives, is tribooxidized during milling and/or
- c) the  $\text{Si}_3\text{N}_4$  powder is admixed with sintering aids or with  $\text{SiO}_2$  or at least one  $\text{SiO}_2$ -forming component either before or during milling.
3. Use of the silicon nitride materials according to Claim 1 in the construction of machinery and apparatus, in particular in bearings.



The invention relates to silicon nitride substances containing sintering additives and  $\text{SiO}_2$ , a method for producing them and the use of the same.

[illegible]

FIGURE 2

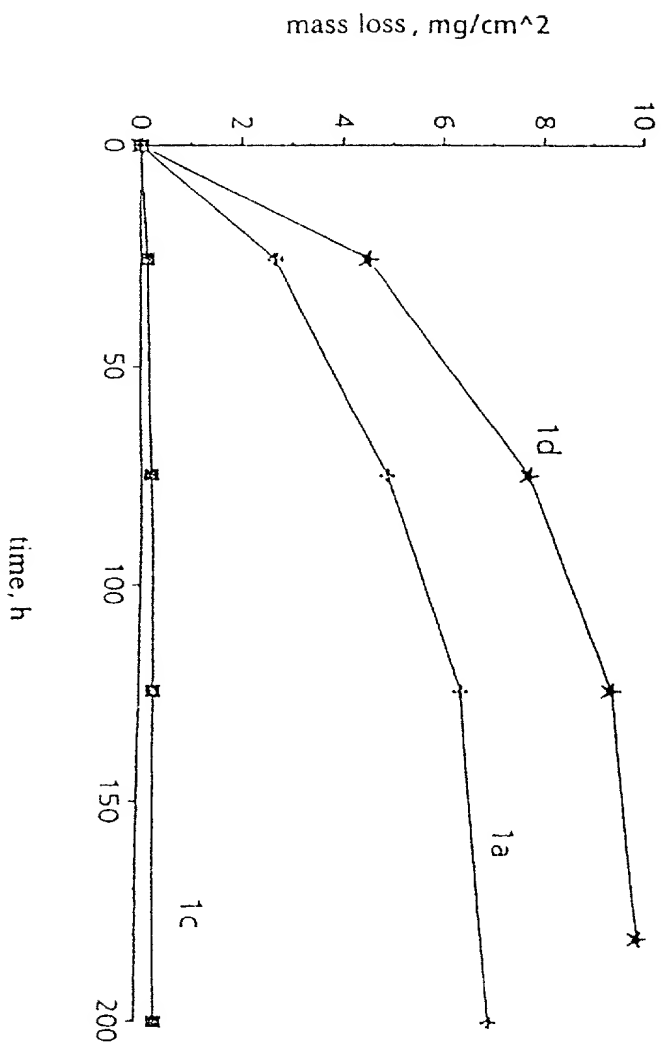
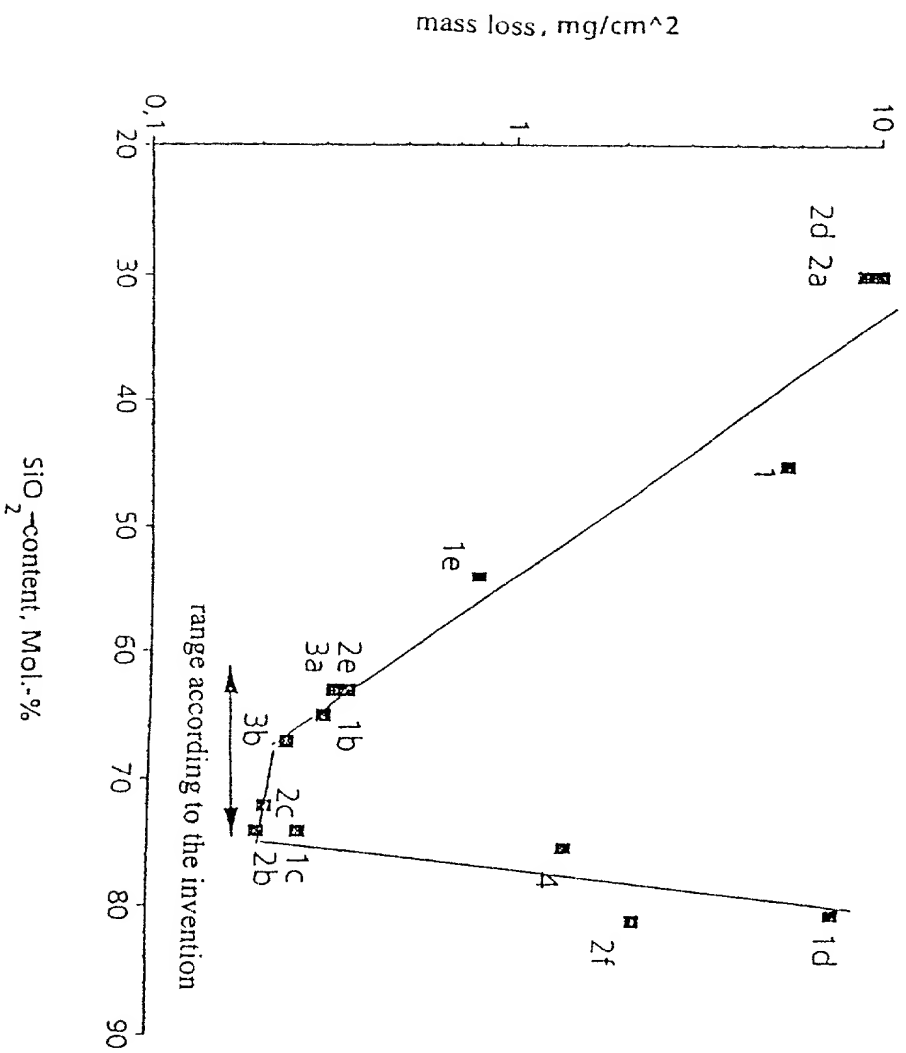


FIGURE 1



09/529680 A 1994-07-20

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought

on the invention entitled

**SILICON NITRIDE SUBSTANCES CONTAINING SINTERING ADDITIVES AND  
SiO<sub>2</sub>, ~~MEHTOD~~ FOR PRODUCING THEM AND USE OF THE SAME  
METHOD**

the specification of which is attached hereto,

or was filed on **October 7, 1998**

as a PCT Application Serial No. **PCT/EP98/06375**

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s), the priority(ies) of which is/are to be claimed:

**197 46 008.9**  
(Number)

**Germany**  
(Country)

**October 20, 1997**  
(Month/Day/Year Filed)

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose the material information as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)

(Filing Date)

(Status)

(patented, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status)

(patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

**Le A 32 647-US**

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

JOSEPH C. GIL, Patent Office Registration Number 26,602  
ARON PREIS, Patent Office Registration Number 29,426  
LYNDANNE M. WHALEN, Patent Office Registration Number 29,457  
THOMAS W. ROY, Patent Office Registration Number 29,582  
RICHARD E. L. HENDERSON, Patent Office Registration Number 31,619  
GODFRIED R. AKORLI, Patent Office Registration Number 28,779  
N. DENISE BROWN, Patent Office Registration Number 36,097  
NOLAND J. CHEUNG, Patent Office Registration Number 39,138  
CAROL MARMO, Patent Office Registration Number 39,761  
DIDERICO VAN EYL, Patent Office Registration Number 38,641

all of Bayer Corporation, Pittsburgh, Pennsylvania 15205-9741

Send Correspondence To:  
Patent Department  
Bayer Corporation  
100 Bayer Road  
Pittsburgh, Pennsylvania 15205-9741

Direct Telephone Calls To:

(412) 777-2349

FULL NAME OF SOLE OR FIRST INVENTOR Gerhard Wötting		INVENTOR'S SIGNATURE <i>Gerhard Wötting</i>	DATE 20.3.00
RESIDENCE D 96450 Coburg, Germany DEX		CITIZENSHIP German	
POST OFFICE ADDRESS Schulstr. 16, D 96450 Coburg, Germany			
FULL NAME OF SECOND INVENTOR Mathias Herrmann		INVENTOR'S SIGNATURE <i>Mathias Herrmann</i>	DATE 03.07.00
RESIDENCE D 01640 Coswig, Germany DEX		CITIZENSHIP German	
POST OFFICE ADDRESS Paul-Schneider-Str. 27, D 01640 Coswig, Germany			
FULL NAME OF THIRD INVENTOR Grit Michael		INVENTOR'S SIGNATURE <i>Grit Michael</i>	DATE 03.07.00
RESIDENCE D 01309 Dresden, Germany DEX		CITIZENSHIP German	
POST OFFICE ADDRESS Haenel-Clauß-Str. 23, D 01309 Dresden, Germany			
FULL NAME OF FOURTH INVENTOR Stefan Siegel		INVENTOR'S SIGNATURE <i>Stefan Siegel</i>	DATE 3.9.00
RESIDENCE D 01189 Dresden, Germany DEX		CITIZENSHIP German	
POST OFFICE ADDRESS Rastatter Str. 5, D 01189 Dresden, Germany			
FULL NAME OF FIFTH INVENTOR Lutz Frassek		INVENTOR'S SIGNATURE <i>Lutz Frassek</i>	DATE 20-03-00
RESIDENCE D 96472 Rödenthal, Germany DEX		CITIZENSHIP German	
POST OFFICE ADDRESS Emstadter Str. 15, D 96472 Rödenthal, Germany			
FULL NAME OF SIXTH INVENTOR		INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP	
POST OFFICE ADDRESS			
FULL NAME OF SEVENTH INVENTOR		INVENTOR'S SIGNATURE	DATE
RESIDENCE		CITIZENSHIP	
POST OFFICE ADDRESS			